MA 2: Magnetic Materials I

Time: Monday 9:30–11:00 Location: H31

MA 2.1 Mon 9:30 H31

Analysis of Local Magnetisation, Composition, and *in Situ* Magnetization Reversal in (Dy,Nd)-Fe-B Core-Shell Sintered Magnets — •Tim Helbig[1], Konrad Löwe[1], and Oliver Gutfleisch[1,2] — [1]TU Darmstadt, Functional Materials — [2]Fraunhofer IWKS Hanau, Germany

One approach to reduce the amount of expensive heavy rare earth elements (RE), such as Dy or Tb, in permanent magnets is to design the grain boundaries of modern high performance NdFeB-type magnets. Their grains consist of a heavy RE rich shell and a $Nd_2Fe_{14}B$ core. Heavy REs are needed to provide high coercivity especially at elevated temperatures, they reduce however the total magnetic moment at the same time. The idea of the shell structures is to use as little Dy as necessary to improve the coercivity of the entire magnet by only concentrating Dy at the "weak point" i.e. the grain boundary. In this work, a core-shell structured (Dy,Nd)-Fe-B sintered magnet was produced through a novel experimental technique involving blending of powders with different compositions and grain sizes and analysed by Scanning Electron Microscope (SEM), Magnetic Force Microscopy (MFM) and Kerr microscopy. It was possible to correlate all used characterisation methods on the same specific area and match chemical composition with local magnetisation. Further, *in situ* magnetization reversal using MFM and Kerr with externally applied magnetic fields were employed.

MA 2.2 Mon 9:45 H31

Magnetic neutron scattering on textured and isotropic Nd-Fe-B-based nanocomposites — •Raoul Weber[1], Andreas Michels[1], Élio Alberto Périgo[1], Ivan Titov[1], Denis Mettus[1], Joachim Kohlbrecher[2], Masao Yano[3], Akira Kato[3], Masaaki Ito[4], and Kiyonori Suzuki[5] — [1]Physics and Materials Science Research Unit, University of Luxembourg — [2]Paul Scherrer Institut, Switzerland — [3]Toyota Motor Corporation, Japan — [4]Institut Néel, Grenoble, France — [5]Monash University, Clayton, Australia

Nd-Fe-B nanocomposite permanent magnets, which consist of exchange-coupled hard ($Nd_2Fe_{14}B$) and soft ($\alpha-$Fe) magnetic phases, are of potential interest for electronic devices due to their preeminent magnetic properties such as high remanence and magnetic energy product. Based on recent density-functional-theory calculations which predict a dependency of the exchange coupling on the crystallographic orientation at the interface between $Nd_2Fe_{14}B$ and $\alpha-$ Fe (ferromagnetic $\leftrightarrow$ antiferromagnetic), we have carried out a comparative study of the magnetic microstructure of textured and isotropic nanocrystalline $Nd_2Fe_{14}B/\alpha-$ Fe by means of magnetic-field-dependent small-angle neutron scattering.

MA 2.3 Mon 10:00 H31

Influence of Ce and Co substitution on the magnetocrystalline anisotropy of $(NdCe)_2(FeCo)_{14}B$ single crystals — •Bahar Fayyazi, Konstantin Skokov, Christoph Schwöbel, and Oliver Gutfleisch — Material Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany

Due to recent pressures on the availability and cost of rare-earth (RE) metals, especially for Nd and Dy which are essential for high performance $Nd_2Fe_{14}B$ -type permanent magnets, it is a priority to develop materials that rely less on scarce RE-elements. Cerium is the most abundant and low cost rare-earth element without significant supply restrictions. At the same time, $Nd_2Fe_{14}B$ and $Ce_2Fe_{14}B$ adopt the same crystal structure and many research efforts around the world are directed toward substitution of Nd, Tb and Dy in $Nd_2Fe_{14}B$ -type permanent magnets by Ce (so-called rare balance magnets) without significant concurrent reduction of remanent magnetization, coercivity and Curie temperature, what, in turn, is a really challenging task. In this work, we report on magnetocrystalline anisotropy and spontaneous magnetization of $(NdCe)_2(FeCo)_{14}B$ single crystals. Anisotropy constants K_1, K_2 and K_3 were exstracted from experimental field dependences of magnetization measured along [001] [100] and [110] crystallographic directions. We also explored how the change of the composition affects effective magnetic moment, temperature of spin-reorientation transition and Curie temperature.

MA 2.4 Mon 10:15 H31

Magnetic properties of hard magnetic $(Fe,Cr)_3Sn_2$ intermetallic compounds — •Dagmar Goll, Ralf Loeffler, Johannes Herbst, Christoph Frey, Susanne Goeb, Tvtrko Grubesa, Dominic Hohs, Andreas Kopp, Ulrich Pflanz, Roland Stein, and Gerhard Schneider — Aalen University, Materials Research Institute (IMFAA), Aalen, Germany

Novel magnetic materials filling the wide-open gap between cost-efficient hard ferrites and expensive high-performance Fe-Nd-B are desirable for efficient energy converters. By experimental bulk high-throughput screening Fe-Sn-X, rare earth free $(Fe,Cr)_3Sn_2$ with high potential as new hard magnetic compound has been discovered. For fabricating the compound in large amounts, a cycle procedure (grinding-pelletizing-annealing) has been used. By quantitative microscopy and magnetometry promising intrinsic magnetic properties $J_S \approx 0.9$ T (saturation polarization), $K_1 \approx 1.7$ MJ/m^3 (anisotropy constant and $T_C \approx 612$ K (Curie temperature) have been found with K_1 increasing with temperature. According to X-ray diffraction the crystal structure of $(Fe,Cr)_3Sn_2$ is modified compared to Fe_3Sn_2 (*project supported by BMBF*).

MA 2.5 Mon 10:30 H31

Investigation of low temperature phase MnBi with temperature dependent first-order reversal curve measurements. — •Shreyas Muralidhar[1,2], Joachim Gräfe[1], Yu-Chun Chen[1], Helmut Kronmüller[1], Gisela Schütz[1], and Eberhard Goering[1] — [1]Max Planck Institute for Intelligent Systems, Stuttgart — [2]Universität Stuttgart

The rare earth free intermetallic compound MnBi in the low temperature phase (LTP) is a permanent magnet with sufficiently high energy product (BH)max for high temperature applications. At 500K LTP-MnBi has the highest coercivity. A striking property of the LTP-MnBi is the positive temperature coefficient of coercivity. To understand the behavior of micro coercivities and interaction field leading to the effective behavior of the coercivity, a study of the First-Order Reversal Curve (FORC) diagrams was required. A detailed FORC analysis has been performed for the first time on LTP-MnBi, at various temperatures. This gave an insight into the influence of microstructural properties on the magnetic properties of the hard magnetic system. The temperature dependent FORC analysis indicated a unique variation of the distribution from narrow-broad-narrow along the coercivity axis. A semi-quantitative explanation for the behavior of the micro-coercivities can be provided utilizing the structural information and its influence on the nucleation field of the material. A better understanding of the coercivity behavior linked with the microstructure helps to tailor the synthesis methods to obtain high performance permanent magnets.

MA 2.6 Mon 10:45 H31

Searching room temperature martensite phases of Fe-Mn-Ga — Johannes Kroder, •Semih Ener, Konstantin P. Skokov, and Oliver Gutfleisch — Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany

For the search of new permanent magnet materials a bulk high-throughput method is needed. One possible candidate for bulk high-throughput screening is simple and low-cost reactive crucible melting method. The tetragonal phases of the Heusler alloys may show potential as a permanent magnet material. In this work we successfully applied the reactive crucible melting method to the Ni-Mn-Ga and Fe-Mn-Ga ternary Heusler systems. The room temperature ternary phase diagram of Fe-Mn-Ga is reported for a specific composition region. The most interesting observed hard magnetic material is $Mn_{38.5}Fe_{32.5}Ga_{29}$ with the remanent magnetization of 20 Am^{2}kg^{-1} and a coercivity of 0.33 T. Observed relatively high coercivity (without any exchange bias effect) shows the possibility of using the Heusler-type materials as hard magnetic materials.